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REPORT

OF THE

SUPERINTENDENT

OF THE

UNITED STATES NAVAL OBSERVATORY

FOR THE

FISCAL YEAR ENDING JUNE 30, 1899.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
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UNITED STATES NAVAL OBSERVATORY,
Washington, D. C., October 2, 1899.

SIR: I have the honor to submit the annual report of the operations of the United States Naval Observatory for the fiscal year ending June 30, 1899.

DEPARTMENT OF ASTRONOMICAL OBSERVATIONS.

The report of the Astronomical Director is as follows:

UNITED STATES NAVAL OBSERVATORY,
Washington, D. C., September 30, 1899.

SIR: In compliance with paragraph 23 of the regulations for the government of the United States Naval Observatory, I have the honor to submit the following report concerning the operations of the astronomical department for the fiscal year ending June 30, 1899.

THE 26-INCH EQUATORIAL TELESCOPE.

[Prof. STIMSON J. BROWN, U. S. N., in charge.]

As usual, this instrument has been employed almost exclusively on faint and difficult objects, which could not well be reached by smaller telescopes, and in spectroscopic observations for measuring the motions of stars in the line of sight. The work accomplished during the year was as follows:

In order to obtain some idea of the effect of irradiation upon the observed diameters of Mercury and Venus, observations of these planets in all parts of their orbits were continued throughout the year, whenever the seeing was sufficiently good to promise valuable results. The total number of measurements obtained was 14 of Mercury and 43 of Venus. It soon became evident that the irradiation was a function of the magnifying power, and since April 24, 1899, observations have been made, whenever practicable, with two powers, namely, a low one of 200 diameters, and a high one of either 606 or 785 diameters. Satisfactory measurements of the diameter of Venus were obtained in that way on 11 days, and the results reduced to unit distance are as follows:

Quantity measured.	Magnifying power employed.		Difference.
	200.	606 or 785.	
	″	″	″
Mean of observed diameters	17.99	17.38	+0.61
Maximum observed diameter	18.32	17.50	+0.82
Minimum observed diameter	17.48	17.12	+0.36

The larger diameters were found when the sky was clear and the images bright, and the smaller when the atmosphere was thick and the images faint. Increase of power also reduces the brightness of the images, thereby diminishing the irradiation, and for that reason the diameters measured with the higher powers are doubtless the most correct. At all events, the results thus far obtained show the futility of expecting consistent data for the diameters of the planets from observations made with filar micrometers, armed with all sorts of powers, and applied to telescopes whose apertures range from 3 to 40 inches. An attempt will be made to eliminate irradiation absolutely by substituting for the spider lines of the micrometer a bar broad enough to cover the entire planet, and making the measures by noting the position of the screw at which complete occultation occurs.

Between July 1 and August 16, 1898, differences of right ascension and declination of the fifth and eighth satellites of Saturn (Rhea and Iapetus) were measured on sixteen nights. Owing to the extreme southern declination of the planet, Iapetus was generally a faint object, especially at its eastern elongation, and although every clear night was utilized, only 35 observations were obtained. Nevertheless, this is a more satisfactory outcome than was got in 1894, 1895, and 1896, when only 25 observations were made at each opposition. On account of the large angle under which the orbits of the satellites appeared it was necessary to use a power of only 200 in order to obtain a sufficient field of view. At recent previous oppositions a power of 400 was used, but Professor Brown is of opinion that the lower power gave a distinct gain in ease of observation, and perhaps also in accuracy.

The asteroid Niobe was observed on two nights, and then work on it was discontinued because its brightness was found to be sufficient to make it an easy object for the 12-inch telescope.

The asteroid Eros was observed on ten nights between September 11, 1898, and January 2, 1899; and that was thought enough in view of the discovery of impressions of it upon the photographic plates made at Harvard College Observatory during the oppositions of 1893–94 and 1896.

Observations of double stars were made from August 17 to September 21, 1898, and from April 10 to June 6, 1899; the total number of measures secured being 149—most of them upon very difficult objects.

During August and September, 1898, the atmospheric conditions were so bad that it was possible to use a power higher than 400 on only two nights, and as the stars to be observed were usually difficult on account of great differences in the relative magnitudes of their components, but little was accomplished. In April and May, 1899, a period of fine observing weather occurred, during which good measures were secured on many difficult pairs, some of which were below the theoretical limit of separation for a 26-inch telescope. The excellence of this weather is emphasized by the fact that Professor Brown had examined some of these stars on many previous occasions without being able to split them. As an instance of this Σ 1306 may be mentioned. Its components were of the fifth and ninth magnitudes, and although the distance between them is 1.3″, the attempts to measure it here between 1897 and last April all failed except one, while during the fine weather in question measurements were obtained on five nights without difficulty.

During March and April, 1899, Sirius was carefully examined in the early evening twilight whenever the weather would permit, but the companion was seen only once, viz, on March 17, and the measurements then obtained gave position angle 169.9°, distance 4.78″. Little value can be attached to this result until it is confirmed by further observations.

Spectroscopic work for determining the motion of certain stars in the line of sight has been prosecuted tolerably continuously since November, 1898, except from the middle of March to the middle of June, when the spectroscope was undergoing rather extensive alterations at the hands of its maker. The observations were made almost wholly by the photographic method, and in that part of the work Professor Brown was efficiently assisted by Mr. George H. Peters, photographer.

The first measurable photograph of a stellar spectrum accompanied by a hydrogen comparison spectrum was obtained from α Aurigæ on December 5, 1898, the exposure being forty minutes for the star and two minutes for the hydrogen lines. During the period from November, 1898, to February 27, 1899, a total of 38 measurable plates was secured upon α Tauri, α Aurgiæ, α Canis Majoris, α Canis Minoris, α Cygni, and ε Cygni; but many more exposures were made which resulted in failure, owing to the telescope being corrected for visual rays, and the consequent difficulty of keeping the star image formed by the photographic rays accurately centered on the slit of the collimator. Much trouble was also found in impressing satisfactory comparison spectra upon the plates, the required exposures being long and difficult to estimate correctly. The latter difficulty was attributed by Professor Brown to lack of power in the induction coils employed.

The successful photographs have been measured upon the large comparator designed by Professor Harkness in 1869 for measuring photographs of solar eclipses and subsequently used for measuring all the photographs of the transits of Venus of 1874 and 1882 which were obtained by the United States parties. Although unnecessarily large for measuring star spectra, and for that reason less convenient than more highly specialized apparatus, it gives extremely accurate results. The displacement of the Hγ line was determined by the well-known method of Vogel, and while the results agree satisfactorily with those obtained by other observers, their accuracy is of a very high order. From the measurement of seven photographs of α Aurigæ the mean velocity of that star in the line of sight was found to be 17.5 ± 0.27 miles per second, and the probable error of the velocity determined from a single plate was ± 0.71 of a mile per second.

As originally constructed, the spectroscope was defective in two respects, namely: First, the walls of the prism box were so thin that the prism train could not be firmly clamped without throwing the spectrum too far out of the optical axis of the camera, and when used with such clamping as was possible the photographic plates sometimes showed a shifting of the whole spectrum, due to displacement of the prisms during the exposure. Second, there was great difficulty in seeing the Hγ image of a star with sufficient clearness to keep it accurately upon the slit, and consequently there was always an embarrassing uncertainty as to the effective exposure, frequently resulting in weak and unsatisfactory negatives.

To remedy these defects, the spectroscope was sent to Mr. Brashear on March 13, 1899, with instructions to substitute for the old prism box a new and much stronger one; to provide a Huggins slit with polished speculum metal jaws for the collimator; to provide two new photographic plate holders, and to furnish a correcting lens which would alter the focal curve of the 26-inch telescope in such a way as to shift the position of minimum focal distance from the Fraunhofer line $E=\lambda\ 5270$ to the neighborhood of $H\gamma=\lambda\ 4341$. These alterations and additions were successfully made and the spectroscope was returned to the Naval Observatory on June 12, 1899. The correcting lens is 2.09 inches in diameter, and when inserted in the optical axis of the 26-inch telescope at a point 20.0 inches from the slit of the spectroscope, it alters the form of the focal curve in such a way as to bring the minimum focal distance very near to the spectral line $H\gamma=\lambda\ 4341$, without sensibly altering the distance of that part of the curve from the object glass. In consequence of this change the Hγ image of a star can now be well seen and can be kept accurately upon the slit of the spectroscope, thereby greatly reducing the required exposures for star spectra and removing most of the uncertainty heretofore existing as to their proper length. In order to reduce the length of exposure required for comparison spectra, Professor Brown is anxious to obtain a more powerful induction coil.

In this connection it is interesting to note that several negatives of the spectrum of α Aurigæ, taken before the prism box was altered, were rejected on account of apparent doubling of the lines, which was attributed to shifting of the prism train. Recent discoveries by Professor Campbell at the Lick Observatory indicate that the star is a spectroscopic binary, and the doubling in question was probably due to that fact and not to any defect in the spectrograph.

All micrometical observations made with the 26-inch telescope have been reduced and are ready to be copied for the printer; and all observations of comets and asteroids, together with the reduction and discussion of the observations of the satellites of Mars in 1894 and 1896, and the reduction and discussion of the observations of the satellites of Saturn in 1894–95–96, have been published in the Astronomical Journal. The reduction and discussion of the observations of the satellite of Neptune in 1897–98 are nearly ready for publication in the same journal, and an abstract of the paper was read at the third annual conference of astronomers and astrophysicists, held at the Yerkes Observatory September 6, 7, and 8, 1899. The spectroscopic work has hardly yet passed out of the experimental stage, and none of it has been published.

The 26-inch telescope has remained in excellent order throughout the year, and the steadiness with which its polar axis maintains its position is well shown by the following observations of the coordinates of the latter, relatively to the pole of the heavens:

November 27, 1897, $\xi = +1'\ 16''$; $\eta = +1'\ 44''$
April 5, 1899, $+1\ \ 04$ $+1\ \ 27$

In my report for the fiscal year ending June 30, 1896, the defective character of the construction of the great-equatorial building was pointed out, in that the office rooms, which are necessarily warmed in winter, are separated from the telescope room only by a pair of large double doors without any intervening anteroom, the heavy masonry walls give rise to much radiation, and the temperature in the basement beneath the elevating floor is frequently 10 degrees higher than in the dome above. Under these circumstances, the warm air in the basement finds a ready escape into the telescope room through the various openings connected with the elevating platform, and thus frequently impairs the seeing. To remedy this defect, a detailed plan was worked out by the astronomical director for covering the floor and walls of the space beneath the elevating platform with a double layer of boards seven-eighths of an inch thick, including a layer of tarred paper between them, so as to make the entire construction practically air-tight. The execution of this design was carried out by Mr. John T. Walker between June 14 and July 15, 1899. Its general effect is to completely cover the masonry part of the telescope pier, together with the concrete floor of the cellar, and to inclose the elevating rams, together with the machinery for working them and the connecting water pipes, in a separate compartment capable of being warmed by steam during cold weather. Thus the space beneath the elevating platform can be freely exposed to the outer air at all seasons of the year without risk of freezing the hydraulic apparatus, and as the entire radiating surface is everywhere of wood, which is a bad conductor of heat, there is no apparent reason why the space beneath the elevating platform should be any warmer than that above. It is therefore hoped that all trouble from upward currents of heated air will now cease.

To diminish the chance of heated air entering the dome through the large double doors connecting it with the office rooms, a second pair of double doors has been placed across the hall, 9.5 feet from the original ones; thus in effect creating an anteroom which bars the direct passage of air from the office rooms to the dome.

The dome sheltering the 26-inch telescope is covered with thin plates of galvanized iron, which have sometimes given much trouble in damp weather by causing water to condense on their under surfaces and drip down upon the telescope. To remedy this, a coat of cork paint was applied to the interior surface of the dome in the beginning of August, 1899.

THE 12-INCH EQUATORIAL TELESCOPE.

[Prof. EDGAR FRISBY, U. S. N., in charge.]

From July 1, 1898, until the retirement of Professor Frisby for age on May 22, 1899, this instrument was employed in observing minor planets, comets, occultations of stars by the moon, and eclipses of Jupiter's satellites. The work done was as follows:

Sixteen observations of asteroids were made, namely: 1 of Hebe (6), 2 of Parthenope (11), 1 of Fortuna (19), 1 of Polyhymnia (33), 1 of Freia (76), 2 of Eurynome (79), 2 of Amalthea (113), 1 of Pitho (118), 1 of Juewa (139), 1 of Gallia (148), and 3 of Eros (433).

Perrine's comet, *h* 1898, was observed six times.

Brooks's comet, *i* 1898, was observed eight times.

Fourteen occultations of stars by the moon, and 17 eclipses of Jupiter's satellites were observed.

The above observations have all been reduced, checked, and copied upon the usual forms for publication, and the results of the observations of comets have been printed in the Astronomical Journal.

From May 22, 1899, when Professor Frisby was retired, until July 15, 1899, when Prof. T. J. J. See was given charge of the 12-inch telescope, the only astronomical work done with that instrument was an attempt by Professor Brown to find certain asteroids, which were probably too faint for the power of the object glass, and the search for which was therefore transferred to the 26-inch telescope.

On every Thursday evening throughout the year, weather permitting, the 12-inch telescope was employed by Computers E. A. Boeger, William M. Brown, George K. Lawton, and W. S. Eichelberger for the exhibition of celestial objects to visitors. As usual, permits for these evenings were issued both by the Observatory and by the Bureau of Equipment, but I do not know the total number granted. During the period covered by this report 1,623 names were registered in the visitors' book. This, however, includes both the visitors on Thursday evenings and those between 9 a. m. and 4 p. m., when the Observatory is open to the public on all working days, and any person calling is shown through the buildings by the watchman on duty.

The 12-inch telescope has remained in good condition throughout the year, the only repairs required being those made by Mr. M. E. Kahler during the month of October, 1898. They include remounting the electric lamps used in reading the fine right-ascension and declination circles, so as to obtain a better illumination of the verniers when viewed through the microscopes, repolishing the prisms in the right-ascension reading microscopes, and securing the rod which carries the counterpoise weights more firmly to the object-glass end of the telescope.

THE 9.14-INCH TRANSIT CIRCLE.

[Prof. AARON N. SKINNER, U. S. N., in charge.]

In the work of this instrument, and of the 6-inch transit circle, Professor Skinner has been assisted for the periods specified by the following-named gentlemen: Assistant Astronomer Theo I. King, Assistant Astronomer (promoted from computer August 6, 1898) F. B. Littell, and Computers E. A. Boeger, William M. Brown, and George K. Lawton, throughout the year, except that Messrs. Boeger and Lawton were sometimes detached for temporary service in inspecting nautical instruments and carrying on the time service; Prof. T. J. J. See, U. S. N., from April 3, 1899; Computer M. E. Porter, to July 15, 1898, and Computer W. S. Eichelberger, from December 5, 1898. Miscellaneous Computer F. H. Parsons aided in computing from September 1, 1898, but not in observing. Computer W. S. Eichelberger was transferred from the Nautical Almanac Office to the Observatory on August 15, 1898, but as it was necessary for him to finish some important work upon which he was engaged in the Nautical Almanac Office, Assistant James Robertson, of that office, acted as his substitute in the Observatory from September 7 to December 5, 1898.

As the reductions of the German Astronomical Society's zone, lying between 13° 50′ and 18° 10′ of south declination are still far from finished, it was thought best to limit the work of the transit circle during the present year to observations of the sun, moon, and planets, together with such stars as were wanted for special purposes, and the minimum number of ephemeris stars necessary for determining instrumental constants.

In order to afford an opportunity for necessary alterations and repairs to the 9.14-inch transit circle and its appurtenances, the whole observing force was transferred from that instrument to the 6-inch transit circle on June 5, 1899. Thus the observations actually made during the twelve months ending June 30, 1899, were obtained partly with the large transit circle, and partly with the small one, but the series was perfectly continuous, and for the sake of clearness it seems best to specify all the observations in the following table:

Objects.	9.14-inch transit circle.	6.0-inch transit circle.	Total.
Ephemeris stars	2,358	281	2,639
Sun	164	16	180
Moon	138	14	152
Mercury	92	8	100
Venus	140	10	150
Mars	32	....	32
Jupiter	39	....	39
Saturn	19	12	31
Uranus	22	15	37
Neptune	40	....	40
Niobe (71)	6	....	6
Wire interval stars	....	45	45
Miscellaneous stars	38	....	38
Screen observations	50	....	50
Total	3,138	401	3,539

In compliance with special requests, results of our observations of stars have been furnished to certain parties, as follows:

July 15, 1898, to Prof. C. L. Doolittle, Flower Observatory, Philadelphia, Pa., 6 star places; September 14, 1898, to Dr. Berthold Cohn, Vienna, Austria, 1 star place; September 26, 1898, to Prof. W. J. Hussey, Lick Observatory, California, 5 star places; November 15, 1898, to

Prof. S. J. Brown, United States Naval Observatory, 3 star places; January 14, 1899, to Prof. C. D. Perrine, Lick Observatory, California, 6 star places; February 3, 1899, to Prof. Ormond Stone, University of Virginia, Charlottesville, Va., 3 star places; February 4, 1899, to Prof. E. C. Pickering, Harvard College Observatory, Cambridge, Mass., 7 star places; February 4, 1899, to Prof. S. J. Brown, United States Naval Observatory, 2 star places, and February 4, 1899, to Prof. Edgar Frisby, United States Naval Observatory, 1 star place.

The reductions of the observations of the ephemeris stars are so arranged as to give absolute right ascensions and declinations; while the reductions of the observations of the sun, moon, planets, and miscellaneous stars are based upon the star places given in the American Ephemeris, and are intended to be wholly differential. But the star places of the American Ephemeris were changed in the volume for 1900, the list printed from 1881 to the end of 1899 being compiled from several different sources, while that used after January 1, 1900 is wholly from Prof. Simon Newcomb's Catalogue of Fundamental Stars for the Epochs 1875 and 1900, Reduced to an Absolute System. Meridian observations of the sun, moon, and planets were begun at the new Naval Observatory on October 10, 1894, and from that date to April 7, 1898, all of them were reduced with the star places of the current volumes of the American Ephemeris, no intimation having then been made public that any systematic changes in these places were contemplated. To have continued the use of the American Ephemeris in that way would have led to a break in the uniformity of the results of observations at the new Naval Observatory when the places of the fundamental stars were changed in 1900, and to avoid that difficulty it was decided to anticipate the change in the Ephemeris by correcting all the reductions from October 10, 1894, so as to make them conform to the standard places given in Professor Newcomb's fundamental catalogue for the epochs 1875 and 1900. That correction involved a good deal of labor, but it has been carried out during the current fiscal year, and as the same fundamental star places will be used for the remainder of this century, all the differential meridian observations made at the new Naval Observatory will have been reduced with the fundamental star places which are likely to be generally adopted at the beginning of the twentieth century.

The current reductions are practically completed to January 1, 1899. From that date to May 15, 1899, they are two-thirds completed, and from May 15 to June 4 they are entered on the reduction sheets ready for computation. On the morning of June 5, 1899, the entire observing force was transferred from the 9.14-inch transit circle to the 6-inch transit circle, and as the latter is a new instrument the determination of its constants has necessarily delayed the reduction of the observations made with it.

The reduction of the sun, moon, and planet observations has occupied the whole computing force so fully that comparatively little work has been done on the zone observations during the current year. That accomplished is as follows: In right ascension the reduction from the date of observation to 1900.0 has been interpolated from the tables for the zones 65 to the end of 164, and checked to the latter point, and for the remaining zones 165 to 184, where interpolation can not be economically used, the same reduction has been commenced for the individual stars. The summation of the reductions necessary to give the mean right ascension for 1900.0 has been completed for the first 45 zones. In declination the reduction from date to the beginning of the year of observation has been interpolated from the tables for the zones 60 to the end of 164, and checked to the latter point, and for the remaining zones the same reduction has been commenced for the individual stars. The work yet left undone is the interpolation of the reduction in declination from the beginning of the year of observation to 1900.0, and the application of the equator points to convert the circle readings into declinations for the same date. It is expected that in the course of the next twelve months the computations will be sufficiently advanced to show what stars are so discrepant as to require reobservation.

The 9.14-inch transit circle having been hastily brought into use in 1893, many of the fittings about it were of a temporary character, and in the beginning of 1899 it was impaired by long-continued service, and greatly in need of a thorough overhauling. Nevertheless, it did not seem wise to interrupt the series of meridian observations with this instrument until they could be taken up by the 6-inch transit circle, and owing to unavoidable delays the latter was not in working order until the beginning of June, 1899. The transfer of the observing force then followed immediately, the last observation with the 9.14-inch transit circle being made on June 3.5, and the first with the 6-inch transit circle on June 4.9.

On June 5–6, 1899, the temporary steps and other fittings around the marble piers of the 9.14-inch transit circle were removed, and on June 8 the most westerly of the two piers was shifted 0.20 inch to the north, in order to bring the screws for adjusting the azimuth of the telescope to the middle of their runs. On the afternoon of the same day the transit circle was completely dismounted, and the two piers were made ready for the stonecutters to effect some necessary alterations in their form.

When the instrument was reconstructed in 1891–92 the marble piers were shortened by simply cutting 23.0 inches from the rectangular part of their tops, and ever since the observers have complained of a difficulty in getting their eyes to the circle microscopes, on account of the batter of the piers commencing at a point much too high up. To remedy this it was necessary to recut the piers in such a way as to extend the rectangular portion downward to a distance of 31.75 inches from their tops, and to form an even batter from thence down to the floor of the observing room. That work occupied three stonecutters from June 10 to June 17. During its progress a large natural crack developed on the eastern side of the eastern pier, and a piece of marble nearly a foot square spalled off, penetrating in its deepest part about half an inch below what should have been the finished surface.

Between June 19 and July 1 the iron tracks for carrying the reflection apparatus were altered so as to make them more rigid; the floor for a width of 56 inches was relaid from the south collimator pier, across the turntable, to the north collimator pier, and from the turntable to the northeast corner of the observing room; a new well was constructed for the mercury basin used in determining the nadir point, and new oak tracks for carrying the reversing carriage were put in place. Finally, between July 3 and July 17, new ash platforms and steps, neatly finished and varnished, were built around the marble piers by Mr. Charles A. Langley, and that completed the woodwork.

On July 17 and 18, 1899, Mr. H. C. Cleve, the observatory instrument maker, remounted the 9.14-inch transit circle, and, in accordance with my instructions, he attached the circle microscopes by means of the original holders instead of by the brass rings which had been substituted for them when the instrument was rebuilt in 1892–93. At the old Observatory there had always been great difficulty in reversing the telescope in its Ys, on account of faulty action of the reversing carriage. In November, 1898, the wheels of this carriage were altered by Messrs. Warner & Swasey, in order to adapt them to the new system of oak tracks, which were put down when the floor was relaid in June 1899, and the present remounting of the instrument afforded the first test of the working of the apparatus under the new conditions. It was not more satisfactory than before, but investigation soon showed that the trouble arose from the position of the vertical axis of the carriage, which was about 0.19 inch too far east and not precisely plumb. In the course of the next three days both of these difficulties were completely remedied by slightly diminishing the diameter of the wheels on the western side of the reversing carriage and shifting the position of the hollow oak track in which they run, and since then the apparatus has worked with the greatest precision.

On January 17, 1899, the telescope micrometer was partially cleaned and oiled without being removed from the instrument, and on February 21 the right-ascension micrometer screw was found bent, but it was successfully straightened without permanent injury.

When the transit circle was rebuilt in 1892–93, certain changes were made in the telescope micrometer, in consequence of which only one of its three eyepieces can now be brought to focus on the webs, the illumination for showing bright webs in a dark field has been so much impaired that faint objects can not be observed, and the action of the micrometer has been rendered otherwise unsatisfactory without being positively inaccurate. In my opinion, it should be restored as nearly as possible to its original construction, but I fear there is scarcely time to do so before my retirement, and I must therefore content myself with trying to improve the bright wire illumination. To that end Mr. Cleve has readjusted the position of the tubes which carry light to the reflecting prisms in the eyepiece, but the result is not yet entirely satisfactory, and other changes will probably be necessary.

A large ladder mounted on wheels for use in observing the nadir point, and some smaller steps for various purposes, all made of ash, neatly finished and varnished, were procured in September, 1898, to replace similar furniture of a more temporary character. In the end of June, 1899, Messrs. Warner & Swasey re-covered the old hanging level of the 9-inch transit circle with leather and fitted it with a new bubble tube, and at the same time they also supplied a new hanging level of improved construction, to be used in the event of any trouble with the old one. New lanterns, lantern stands, and other fittings for illuminating the transit circle, and a switch board for controlling the electric lights, have been ordered, but are not yet in place.

THE 6.0-INCH STEEL TRANSIT CIRCLE.

An account of the mounting of this instrument in the west transit-circle room was given in my last annual report. The work done in that connection since then has been as follows:

Two leather caps were provided on July 20, 1898, to protect the long focus lens used in viewing the meridian mark, and on September 28, 1898, there was received a large ladder mounted on wheels for use in observing the nadir point, together with some smaller steps for various purposes, all made of ash, neatly finished and varnished.

A carefully designed meridian mark has been erected 387.6 feet north of the axis of the 6-inch transit circle, to be viewed through a lens of 6 inches aperture and 371.7 feet focus, mounted on the northern end of the northern collimator pier. The mark consists of a hole 0.020 inch in diameter, drilled in a phosphor-bronze plate, which is mounted, without any adjustment whatever, upon a massive pier of masonry laid in Portland cement. The pier was begun December 12, 1898, and finished June 1, 1899. It has a concrete foundation 6.0 feet square by 4.42 feet thick, upon which rests a brick pier 36 inches square and 34 inches high, covered by a white marble capstone 38 inches square and 4 inches thick. The iron mounting for the phosphor-bronze plate was securely fastened to the marble capstone on June 2, 1899, and the hole which constitutes the actual mark was located and drilled on June 3, 1899. The mark, and all the masonry connected with it, is covered by a wooden house measuring 10.2 feet square and 7.0 feet high in the inside, the building of which was begun on August 8, 1899, and completed on September 13, 1899.

The construction of an electric conduit connecting the west transit-circle house with its meridian mark and with the alt-azimuth house was begun December 22, 1898, but bad weather set in almost immediately after, and the work was not completed until May 10, 1899. On June 5 to June 7, 1899, six lead-covered electric cables were strung through this conduit for the electric light and chronograph circuits which it was designed to carry.

Although the 6-inch transit circle is provided with the usual screws for adjusting the level and azimuth of the telescope axis, the original design of the instrument contemplated the insertion of steel plates of a proper thickness between the foundation plates and the drums which carry the Ys, and, after all adjustments had been accurately made, the bolting down of the drums directly upon these plates, thus in effect doing away with all adjusting screws, and converting the instrument into one solid mass of steel from the marble piers to the Ys. This work proved somewhat laborious, on account of the extreme accuracy required in the thickness of the plates, and it was delayed by the necessity for lengthening the threads on the screws for adjusting the azimuth, and elongating the holes in the drums through which the clamping screws pass, in order to obtain a sufficient range of action, but it was successfully accomplished between April 7 and May 11, 1899. The circle reading microscopes were adjusted on May 17, and most of the fixtures for lighting the instrument and the observing room, both with gas and electricity, were put in place between May 20 and May 31. Finally, in the latter half of May, the thermometer box on the north end of the observing room was lowered from a height of 13.0 feet above the floor to a height of 6.0 feet, and the unavoidable damage done to the walls of the building by this alteration was repaired.

The above-described work did not by any means complete the fitting up of the west transit-circle room, but it did bring the instrument into a usable condition, and owing to the urgent necessity of beginning the alterations and repairs on the 9-inch transit circle, the whole observing force was transferred to the 6-inch transit circle on June 5, 1899, as already stated. Since that date the latter instrument has been constantly employed in making all necessary observations of the sun, moon, planets, and stars, and has proved entirely satisfactory in every respect, except a rather large unsteadiness in the azimuth. The cause of that defect has not yet been precisely determined, but the unusual solidity of all the metal parts of the instrument seems to negative the idea that it can be in them. A similar unsteadiness which existed in the 8.52-inch transit circle while it was mounted at the old Naval Observatory has entirely disappeared since it was remounted upon the same piers at the new Naval Observatory, and this seems to indicate that the unsteadiness was due to something in the foundation upon which the piers stood, and not to anything either in the construction of the instrument or in the piers themselves. The 6-inch transit circle has not sufficient optical power to reach the great bulk of the asteroids, and for that reason the observing force will be returned to the 9.14-inch transit circle at the earliest practicable moment.

The sidereal clock, E. Howard & Co., Boston, No. 626, which was used in observing the transit of Venus at Queenstown, New Zealand, in December, 1874, was mounted in the west transit-circle room on August 29, 1899, for use as a counting clock. Some other fittings are still needed, among which may be mentioned a switch board to facilitate the control of the electric lights which illuminate both the 6-inch transit circle and the observing room. It was ordered some time ago, but has not yet been received.

THE PRIME VERTICAL TRANSIT INSTRUMENT.

[Assistant Astronomer GEORGE A. HILL, in charge.]

This instrument, in connection with the 5-inch alt-azimuth instrument, has been used throughout the year for determining variations of latitude, and the constants of aberration and nutation; the methods employed being those described in former reports, with the addition of the employment of the alt-azimuth instrument as a vertical circle to observe the declination of α Cygni at every possible culmination, both day and night. α Lyræ culminates 14′ south of our zenith, and $2^h\ 04^m$ later α Cygni culminates 5° 59′ north of our zenith. Consequently, the zenith plays between the two stars, and while the changes in the half sum of their declinations will be the latitude variation, the differences of their declinations should be constant, thus affording a very complete check on the accuracy of the work.

The number of observations obtained during the twelve months ending June 30, 1899, was as follows: With the prime vertical transit instrument, θ Aurigæ, 21; α Lyræ, 112. With the 5-inch alt-azimuth instrument used as a zenith telescope α Canum Venaticorum, 28; γ Bootis, 3; α Lyræ, 125; pairs of stars for latitude by Talcott's method, 10. With the 5-inch alt-azimuth instrument used as a vertical circle, μ Andromedæ, 5; α Ursæ Minoris, above the pole 23, below the pole 43; α Cygni, 96. Total, 466.

During the last fiscal year μ Andromedæ and α Canum Venaticorum were not observed by the prime vertical method, because their transits over the western vertical occurred, respectively, at the same time as the upper and lower culminations of Polaris, and it was deemed more important to observe that star by the vertical circle method. Nevertheless, α Canum Venaticorum was observed as frequently as possible by the zenith telescope method, and on account of the large size of the telescope of the alt-azimuth instrument, it is believed that the results are quite as accurate as they would have been by the prime vertical method.

The observations with the prime vertical transit instrument are completely reduced to April 20, 1899, and are copied on sheets for the printer to July 31, 1899. The observations with the alt-azimuth instrument used as a zenith telescope are reduced to December 31, 1898, and those with the same instrument used as a vertical circle are completely reduced to December 31, 1898, and two-thirds reduced from that date to April 20, 1899.

All our observations for the variation of latitude, both with the prime vertical transit instrument and with the alt-azimuth instrument up to December 14, 1898, have been sent to the Centralbureau der Internationalen Erdmessung, and were used by Dr. Th. Albrecht in his Bericht über den Stand der Erforschung der Breitenvariation am Schlusse des Jahres 1898.

The cord which suspended the driving weight of the sidereal clock, Charles Frodsham, 84 Strand, London, used with the prime vertical transit instrument, was found broken on September 3, and was repaired by the Observatory instrument-maker, the late Mr. William F. Gardner, on October 25, 1898. The electric contacts in this clock have recently given a good deal of trouble, but it was finally traced to oil which ran down onto the contact points. The machinery for reversing the telescope of the prime vertical transit instrument was taken apart and thoroughly cleaned by Mr. M. E. Kahler on January 27, 28, and 29, 1899. Being situated under the floor of the observing room, it is difficult to get at, and having been in constant use since May, 1893, it had become too dirty to work freely. On account of the still unexplained difficulty which occurred in the working of the prime vertical transit instrument, from March 12 to September 24, 1894, it was thought desirable to provide it with a second striding level and an improved apparatus for observing stars by reflection. Drawings and specifications having been made for these articles under my own immediate supervision, they were furnished by Messrs. Warner and Swasey on June 30, 1899.

THE 5.0-INCH STEEL ALT-AZMUTH INSTRUMENT.

[Assistant Astronomer GEORGE A. HILL, in charge.]

The exact position of this instrument is 269.7 feet=$2.666''$ north, and 156.4 feet=0.1319^s west of the center of the clock room.

A very little experience with the alt-azimuth instrument showed that when used as a vertical circle it will measure the declinations of stars with much less probable error than is incident to transit circle observations. In addition to the work described in the foregoing section, it is therefore intended to employ it in determining the declinations of all stars of the American Ephemeris list which are visible in this latitude, and during the past year Mr. Hill has made 742 observations of that kind upon 214 Ephemeris stars. Unfortunately it is impossible to get 51 Cephei, δ Ursæ Minoris and λ Ursæ Minoris at both culminations, because the lower culmination of the first-named star and the upper culminations of the other two occur while Mr. Hill is engaged in observing α Lyræ with the prime vertical transit instrument. All observations made by the vertical circle method are completely reduced to December 31, 1898, and from that date to April 20, 1899, they are two-thirds reduced.

In my last annual report I mentioned that when the alt-azimuth instrument was first brought into use the zenith points given, respectively, by the upper and lower alidade levels differed systematically, and thus impaired the accuracy of the instrument for measuring vertical angles. After much fruitless experimenting the cause of this was discovered in the end of July, 1898. To make the adjustment of the length of the bubbles possible, it is necessary that the levels should be easily removable from the alidade, and for that reason the bubble tubes are mounted in heavy steel boxes whose extremities stand upon small projections in the alidade frame, and are held in place by springs which were originally rather stiff. The necessity for providing means of adjusting the horizontality of the levels gives rise to a difference in the mode of application of the springs at the two ends of each box, but at neither end is there anything which seems capable of producing a strain upon the bubble tubes. Nevertheless, the whole difficulty was finally traced to the action of the springs at one end of each box, and since the strain produced by them was relieved the indications of the two levels have agreed admirably.

When the alt-azimuth instrument is used as a vertical circle each complete observation of an object consists of a pointing and a circle reading with clamp east, and another pointing and circle reading with clamp west. The pointings must therefore be made at a little distance on each side of the meridian, and the most convenient method of defining that distance will depend upon the position of the object. For objects precisely in the zenith the only possible method is to make the bisection at some web of the right ascension reticule, situated sufficiently far from the center of the field; but for objects south of the zenith that plan soon ceases to give sufficient time between the two bisections, and it is then better to turn the instrument out of the meridian by a small known angle, and to make the bisection on the central right ascension web. The easiest way of mechanically defining the required angle was the subject of a series of experiments extending from August 5 to September 15, 1898, when a very simple and satisfactory solution was reached. To facilitate zenith telescope work, there is attached to the vertical axis of the instrument a radial bar, which plays between two stops, one of which arrests the telescope exactly in the meridian when the clamp is east, the other when the clamp is west. By suitably widening both sides of the radial bar the telescope can evidently be arrested at any desired small angle from the meridian, and that is now effected by dropping over the bar a forked piece of brass whose two equal prongs give the necessary increase of width. The fork habitually used arrests the telescope at an interval from the meridian which is traversed by an equatorial star in $3^{m}\ 25^{s}$.

The microscopes for reading the vertical circle of the alt-azimuth instrument were adjusted on September 8, 1898, and again more accurately on April 28, 1899. In the beginning of July, 1899, it was discovered that the horizontal axis of the telescope lacked 5.6″ of being perpendicular to the vertical axis. A form was therefore devised for using the striding level to determine simultaneously the position of the vertical axis and the angle between it and the horizontal axis; and in accordance with tests made in that way the latter angle was brought within 2″ of 90°.

On September 8, 1898, the bubble tube of the upper alidade level was accidentally broken, and on September 10 it was replaced by the bubble tube belonging to the striding level. The latter remained without a bubble tube until June 29, 1899, when a new one, made by A. Pessler, of Freiburg, Saxony, was furnished for it by Messrs. Warner & Swasey. On September 10, 1898, Mr. M. E. Kahler furnished a new prism for the diagonal eyepiece, the old one being slightly chipped. This eyepiece is so much heavier than any of the direct eyepieces, that when in use it throws the telescope seriously out of balance, and to remedy that a special counterpoise weight was provided on July 20, 1899.

The declinations observed with this instrument have not yet been freed from flexure, because there are no collimators available for its determination. To supply this want it has been decided to utilize the collimators of 2.13 inches clear aperture and 35 inches focus, formerly belonging to the 8.5-inch transit circle, and a suitable mounting has been ordered for them, including a lens of about 380 feet focus for viewing a meridian mark. This mounting will be of substantially the same construction as the similar apparatus now in use with the 6-inch and 9.14-inch transit circles, except that it will be made of phosphor bronze instead of steel, because of an unusual difficulty in efficiently protecting it from the weather.

THE 40-FOOT PHOTOHELIOGRAPH.

[Photographer GEORGE H. PETERS, in charge.]

Since October, 1898, a wet collodion photograph of the sun has been taken daily at noon, weather permitting, with the 40-foot photoheliograph, which was mounted in November, 1894. The pictures of the sun are about 4.3 inches in diameter, upon glass plates 7 inches square, and the locality where they are taken is defined by the position of the heliostat mirror, which is 371.5 feet = 3.673″ of latitude south, and 103.2 feet = 0.0871^s of longitude east, of the center of the clock room. This photoheliograph is one of the instruments formerly belonging to the United States Transit of Venus Commission, and is made up of photographic objective No. 2, of 5.05 inches clear aperture, and 469.55 ± 0.084 inches focal length for light of wave length 0.425 microns; heliostat mirror No. V, 6.80 inches in diameter; measuring rod No. VII, having a length of 453.498 inches + 0.00299 inches $(t - 62° \text{F.})$, where t is the temperature, and jaw micrometer No. 8. It was used in observing the transit of Venus on December 8, 1874, at Hobart, Tasmania, and has since been used at the old and new Naval Observatories in observing the transits of Mercury of May 6, 1878, and November 10, 1894, the transit of Venus of December 6, 1882, and the partial solar eclipse of March 16, 1885.

The work of photographing the sun daily at the new Naval Observatory was begun on October 11, 1898, and during the remainder of the fiscal year ending June 30, 1899, negatives were obtained on 122 days. These negatives show spots or faculæ upon 87 days, distributed as follows: Ten days in October, 17 in November, 9 in the first nineteen days of December, 5 in January, 5 in February, 8 in March, 15 in April, 6 in May, and 12 in June.

THE NOVEMBER METEORS.

In consequence of an unfortunate oversight, all mention of the November meteors was omitted from my last two annual reports. The work which should have been described was as follows:

1896.—On the night of November 13–14, Prof. Edgar Frisby, Prof. S. J. Brown, and Computer William M. Brown watched for meteors from 12.27 a. m. until 4.58 a. m., Washington mean time. During that period they observed 136 meteors, distributed as follows: From 12.30 to 1, 12; from 1 to 2, 22; from 2 to 3, 14; from 3 to 4, 46, and from 4 to 5, 42. Two of the observers were always engaged in watching the sky, while the third noted the time of appearance of each meteor, as indicated by the mean-time chronometer John Hutton No. 269. The sky was clear and the moon set. On the night of November 14–15, Assistant Astronomer George A. Hill and Computer G. K. Lawton watched for meteors from 2.38 a. m. until 3.37 a. m., but saw only 9. The sky was clear, and the moon set about 2 a. m.

1897.—On the night of November 13–14 Prof. S. J. Brown and Computer E. A. Boeger watched the eastern sky for meteors, but as the moon was only five days past the full, and within about 46° of the radiant point, only the brighter ones were visible. The number observed was, from 3 to 4 a. m., Washington mean time, 13, and from 4 to 4.40 a. m., 16. On the night of November 14–15 the sky was completely overcast and no observations were possible.

1898.—On the night of November 13–14, the sky was everywhere covered by clouds, and no observations were possible. The following night, November 14–15, was clear and moonless, and Assistant Astronomer George A. Hill, with computors William M. Brown and W. S. Eichelberger of the Observatory, and Assistant James Robertson of the Nautical Almanac Office, watched for meteors from 11.58 p. m. until 5.37 a. m., Washington mean time. During that period they observed 206 meteors, distributed as follows: From 12 to 1, 28; from 1 to 2, 27; from 2 to 3, 47; from 3 to 4, 39; and from 4 to 5, 44. Three of the observers were constantly engaged in watching the sky for meteors, while the fourth noted the time of their appearance, as indicated by the mean-time chronometer Dent No. 49,216. Prof. S. J. Brown and Mr. George H. Peters attempted to photograph these meteors with two of our small cameras designed for eclipse work, which they had temporarily attached to the tube of the 26-inch telescope near the object glass. These cameras were armed with the Dallmeyer portrait lenses 3 C, No. 29,064, and 4 B, No. 31,102, which had, respectively, apertures of 3.50 and 4.50 inches, and focal distances of approximately 8.5 and 15.5 inches. Two plates were exposed in each camera, the first from 2.20 to 3.00 a. m., and the second from 3.14 to 4.03 a. m.; but the only meteor recorded upon them was one about the magnitude of Jupiter, which appeared at 2.45 a. m.

PUBLICATIONS.

Causes incident to the removal of the observatory from the old to the new site have thrown our publications very much into arrears, but every effort is being made to bring them up to date as rapidly as possible.

The separate copies of the Second Washington Catalogue of Stars, upon which Professor Eastman was so long engaged, and which forms Appendix I to the volume of observations for 1892, were received from the Government Printing Office in November and December, 1898, and were promptly distributed.

The volumes for 1891 and 1892 will complete the record of work done at the old Naval Observatory, and the manuscript for both of them was sent to the Government Printer on August 19, 1899. Their contents are as follows:

Volume for 1891.—Observations with the 8.5-inch transit circle from January 2 to June 29 (dismounted in July). Observations with the 26-inch equatorial telescope from January 3 to December 30. Observations with the 9.6-inch equatorial telescope from January 5 to December 31. The magnetic observations for this year have been printed as Appendix II to the volume for 1888. Meteorological observations and results from January 1 to December 31. Appendix I.—Observations of the transit of Venus, December, 1874, part 2.

Volume for 1892.—Observations with the 26-inch equatorial telescope from January 6 to December 13 (dismounted in December). Observations with the 9.6-inch equatorial telescope from March 11 to September 30 (dismounted in October). The magnetic observations for this year have been printed as Appendix I to the volume for 1889. Meteorological observations and results from January 1 to December 31. Appendix I.—The Second Washington Catalogue of Stars.

The manuscript of the volume for 1893 is complete so far as the astronomical and meterological observations are concerned, but it should contain a full description of all the buildings and instruments of the new Naval Observatory, and the preparation of that, together with the accompanying illustrations, will involve a large amount of labor. The volumes for 1894 and 1895 will contain the observations for the German Astronomical Society's zone, lying between 13° 50′ and 18° 10′ of south declination, and their reduction can scarcely be completed before the middle of 1900. The reduction of the observations made during the years 1896 to 1899 is so far advanced that the corresponding volumes can be prepared with great rapidity, and I estimate that the printing of all of them can be accomplished in from three to four years.

In my opinion the work of the Naval Observatory can easily be so arranged that in future the observations of each calendar year shall be completely reduced by the beginning of the next following July, and then, if a full year is allowed for the printing of each volume, the volumes should be issued within eighteen months of the date of the last observations they contain.

NEEDS OF THE OBSERVATORY.

As this is the last annual report which I shall make before my retirement from active service, it seems desirable to record my deep sense of the need existing in this Observatory for at least two more computers, together with a 13-inch photographic telescope and an 8-inch heliometer. Complaints are frequently made that we do less work than other great national observatories, but some of these institutions have forces two or three times larger than our own, and until that disparity is at least partially remedied we can not hope to compete with them. As to the suggested new instruments, the necessity for large photographic telescopes is now so universally recognized that many comparatively small observatories are supplied with them; and although large heliometers are not common, it is well known that in certain lines of work they afford a degree of accuracy which can hardly be attained in any other way. I do not think it necessary to incur the expense of keeping either a large photographic telescope or a large heliometer in constant use here, but I am decidedly of opinion that we should possess such instruments and have them always ready to meet exigencies which arise from time to time.

Very respectfully,

Wm. Harkness,
Professor of Mathematics, U. S. N., Astronomical Director.

The Superintendent U. S. Naval Observatory,
Georgetown Heights, D. C.

REPORT OF THE DIRECTOR OF THE NAUTICAL ALMANAC.

Nautical Almanac Office,
United States Naval Observatory,
Washington, D. C., September 30, 1899.

Sir: I have the honor to submit the following report respecting the operations of the Nautical Almanac Office for the fiscal year ending June 30, 1899:

PRINTING.

The books published during the year were received from the Government Printing Office on the following-named dates: Astronomical papers prepared for the use of the American Ephemeris and Nautical Almanac, volume 6, part 4, Tables of Mars, September 19, 1898; Pacific Coaster's Nautical Almanac for 1899, first edition, October 21, 1898; American Ephemeris and Nautical Almanac for 1899, second edition, January 25, 1899; American Nautical Almanac for 1899, third edition, March 18, 1899; American Ephemeris and Nautical Almanac for 1901, first edition, April 5, 1899. Astronomical papers prepared for the use of the American Ephemeris and Nautical Almanac, volume 8, part 2, Catalogue of fundamental stars for the epochs 1875 and 1900 reduced to an absolute system, April 5, 1899; American Nautical Almanac for 1902, first edition, June 30, 1899; Pacific Coaster's Nautical Almanac for 1899, second edition, June 30, 1899.

DISTRIBUTION OF PUBLICATIONS.

During the fiscal year ending June 30, 1899, the sale and distribution of publications were as follows:

Title.	Sold.	Distributed.	Bureau of Equipment.	Public service.	Total.
American Ephemeris	560	269	117	452	1, 398
American Nautical Almanac	2, 392	....	21	354	2, 767
Pacific Coaster's Almanac	1, 420	....	8	6	1, 434
Astronomical Papers	38	279	....	....	317

The proceeds of the above sales amounted to $1,484.27, and in compliance with law that money has been deposited to the credit of the Treasurer of the United States, on account of public printing and binding.

THE AMERICAN EPHEMERIS.

The law authorizing the publication of the American Ephemeris contemplates the issue of each volume three years in advance of its date, but the extra work incident to the preparation of a series of tables of the major planets of the solar system ultimately retarded the Ephemeris to such an extent that the first edition of the volume for 1901 was not received from the Government Printing Office until April 5, 1899. That was less than twenty-one months in advance of its date, and the necessity for making an effort to bring up arrears became evident, but even then the planetary tables were not entirely out of the way. However, the policy of employing every available computer in the preparation of the Ephemeris had been adopted some time previously, and as the force augmented the work went on with increasing rapidity. At the same time, in compliance with a request from the Navy Department, the Public Printer accelerated the printing, with the result that the first edition of the Ephemeris for 1902 was received on August 9, 1899, and there is every reason to believe that the volume for 1903 will be issued in January or February, 1900. If so, that will be the first time in the history of the American Ephemeris when a volume has been issued so nearly three years in advance of its date.

While the general arrangement of the American Ephemeris for 1901 remains substantially as in the years from 1882 to 1899, some changes have been introduced, which may be briefly stated as follows: First, the difference between the values of the constants of precession, nutation, and aberration given by Struve and Peters, and those adopted by the Paris conference of 1896, has been dealt with in the manner explained in my annual report of last year. Second, Prof. Simon Newcomb's tables of the Sun, Mercury, and Venus, and Dr. G. W. Hill's tables of Jupiter and Saturn have been substituted for the tables which were used in the American Ephemeris for the years prior to 1900. Third, the consolidation of the 175 additional fixed stars with the regular list, which was first effected in the volume for 1900, has been continued. Fourth, to facilitate the computation of ephemerides of stars, a page has been added giving for every tenth day of the year both the Besselian and the Independent star numbers, exclusive of all short-period terms. Fifth, the data for the illuminated disks of planets have been somewhat extended, and the accuracy of the diagrams of the motions of the satellites of Jupiter, Saturn, and Neptune have been considerably improved. Sixth, the explanations of the arrangement, use, and construction of the American Ephemeris have been very carefully revised and rewritten. Seventh, as the star numbers, star places, and other data involving precession, nutation, aberration, and mean obliquity of the ecliptic are not given according to the constants of Struve and Peters in the American Ephemeris for 1900, the values for that year have been appended to the volume for 1901, in order to prevent a break in the continuity of the published data.

The changes introduced in the American Ephemeris for 1902 are as follows: First, a new and more accurate formula has been adopted for the semidiameter of the moon. Second, although four-place logarithms usually suffice for reducing stars from mean to apparent place, greater exactness is sometimes required in dealing with observations for variation of latitude, and on that account the number of decimals in the logarithms of the Besselian star numbers A, C, D, and in the logarithms of the Independent star numbers g and h have been increased from four to five, and the tenths have been added to the minutes in the arcs G and H. Third, the star numbers, apparent places of stars, and other data based on the constants of the Paris conference of 1896 have been placed in a subdivision entitled Part IV. The printing of two distinct sets of constants for precession, nutation, aberration, and mean obliquity of the ecliptic is regarded as a temporary expedient, and Part IV will doubtless be abolished as soon as there is a well-pronounced agreement among astronomers respecting the constants which should be used. Fourth, in the explanations of the arrangement, use, and construction of the American Ephemeris, the formulæ for computing solar eclipses have been somewhat improved and the instructions for predicting occultations at a given place have been completely rewritten.

In the Ephemeris for 1903 two changes will be made, viz: First, the adopted apparent semidiameter of the sun at mean distance will be increased from 960.78″ to 961.50″, in accordance with a recent investigation by myself, which rests upon 35,842 meridian observations made at Greenwich, Paris, Washington, Konigsberg, Madras, Milan, Dorpat, Modena, and Seeberg. Second, the ephemeris of σ Octantis will be given for every day instead of for every tenth day, in order to permit the inclusion of the short-period terms in the nutation, which affect the right ascension of the star by a full half second of time.

NEW TABLES OF THE PLANETS.

At the date of my last annual report Professor Newcomb's new tables of Mars were in the hands of the printer, and the manuscript of his tables of Uranus and Neptune was still incomplete. The first issue of the tables of Mars from the Government Printing Office occurred on September 19, 1898, and they were made available to astronomers as soon as possible thereafter. The completion of the tables of Neptune and Uranus occupied more time than was anticipated, and the respective manuscripts were not sent to the Public Printer until October 1, 1898, and March 2, 1899. The first installment of printed copies of the tables of Neptune was received from the Government Printing Office on July 17, 1899, and at the date of this report the printing of the tables of Uranus is understood to be completed, but no stitched copies of the work have yet been received.

NEW INVESTIGATIONS.

For some time past the office has been obliged to use rather weak places for many stars occulted by the moon, and to meet that difficulty I have recently begun work on the formation of a catalogue of about 2,500 zodiacal stars. It will be based upon the same fundamental data as Professor Newcomb's "Catalogue of fundamental stars for the epochs 1875 and 1900, reduced to an absolute system," which was issued in April, 1899.

The elements used in the American Ephemeris for the satellites of the outer planets of the solar system are so unsatisfactory and inconsistent that some months ago I began a revision, which should extend to nearly all of them. The work thus far accomplished has been confined to the satellites of Mars and the fifth satellite of Jupiter, for which the determination of new elements, based upon all available observations, is about three-fourths done.

My approaching retirement from active service will prevent me from completing either the catalogue of zodiacal stars or the revision of the elements of the satellites. At present both undertakings are advancing very slowly on account of the whole computing force being employed on the current work of the Ephemeris, but after the beginning of the year 1900 the conditions will be more favorable for rapid progress.

Very respectfully,

WM. HARKNESS,
Professor of Mathematics, U. S. N., Director Nautical Almanac

The SUPERINTENDENT U. S. NAVAL OBSERVATORY,
Georgetown Heights, D. C.

DEPARTMENTS OF NAUTICAL INSTRUMENTS, AND OF THE GENERAL STOREKEEPER.

SIR: I have the honor to submit the following report of the department of nautical instruments and of the general storekeeper for the fiscal year ending June 30, 1899.

From the beginning of the year until September 24 these departments were in charge of Prof. Stimson J. Brown, U. S. N.; from that time until June 20, 1899, in charge of Lieut. A. N. Mayer, U. S. N.; from June 20 to June 28 in charge of Clerk R. H. Coker. I reported for duty on June 28.

This department continues to have charge of the purchase of nautical instruments for the entire service and of their issue to ships; it is also the depository of nautical instruments turned in by ships at the various navy-yards.

During the years 1895 and 1896 specifications were prepared for all classes of instruments to serve as a guide to the makers and dealers, and to insure a high standard of excellence for instruments accepted for purchase. To inspect these instruments in accordance with specifications requires the use of instruments of special mathematical and scientific design and the use of mathematical formulæ. It is in this way only that errors of instruments can be determined, so that the storekeeper may find out whether he is justified in accepting the instrument and tabulating the corrections, or if the error is so large as to show a radical defect which should cause the instrument to be rejected. The Observatory is the only place under the Navy Department which is fitted with the necessary inspecting apparatus, or where this work can be carried on. It seems to me that this work is of the highest importance, both to the naval service and to the makers. For only by the use of instruments whose mathematical errors have been determined can the navigation or surveying work of naval officers have a final scientific value. And only in this way can the makers be sure that their instruments are constructed on mathematical principles, or learn how to correct errors of construction. In spite of the apparent importance of this work there has been no officer specially detailed to carry it on since Lieut. T. M. Brumby was detached in October, 1897. Mr. E. A. Boeger, one of the computers in the astronomical department, has occasionally carried on this inspection when his services could be spared from his proper work. But the prolonged and tedious character of the work is enough to employ the whole time of one person, and in no other way can the inspection be made full and satisfactory. Instruments returned to the Observatory are rarely found to be in a condition for reissue. The ordinary wear and tear of service cause the best of them to need some repairs. The United States Coast and Geodetic Survey has shops and machinery and mechanics of its own where such repairs are made. The practice of the Observatory has been to call a survey to determine what instruments can be repaired, what have been rendered useless, and what can be reissued. Instruments recommended for repairs are let out by contract to some instrument maker of the city for this purpose. When returned they need a further inspection, and this would give additional employment to an inspector of nautical instruments. I therefore urge the importance of keeping filled the detail of an officer to this special duty.

The following table shows the number of instruments purchased and the number issued to ships during the year by the general storekeeper's department:

Nautical instruments inspected, purchased, and issued.

Instrument.	Purchased after inspection.	Issued.
High-grade sextants	20	9
Ordinary sextants		22
Surveying sextants	20	24
Octants	1	38
Binocular glasses	150	219
Spyglasses:		
Quartermaster	100	140
Officer of the deck		59
Three-arm protractors	50	23
Thermometers	306	164
Aneroid barometers	50	35
Cases captain's reading glasses	50	21
Navigators' dividers	100	57
Psychrometers	25	23
Deck clocks	62	73
Boat clocks		59
Yacht clocks	100	73
Clinometers	25	25
Parallel rulers (Sigsbee)	100	27
Parallel rulers, 15, 18 and 24 inch	125	63
Cases drawing instruments	25	18
Standard steel tapes		9
Surveyors' chains		3
T squares	25	11
Artificial horizons		16
Index and horizon sextant glasses, sets	60	45
Splines and weights, sets		3

The aggregate value of the instruments purchased was $18,525.92. There were made 226 shipments of instruments, the invoice value of which was $36,204.43.

In addition to the above instruments received by purchase, there was a large quantity of nautical instruments received from various navy yards and vessels going out of commission, upon which it was necessary to have a board of survey and appraisal appointed to determine those needing and warranting repairs, and to condemn those unfit for repairs. The instruments repaired have been placed in store for issue, and those unfit for repair have been condemned and are held for the next public sale.

Very respectfully,

B. W. HODGES,
Lieutenant, U. S. N.,
Head of Department and General Storekeeper.

DEPARTMENT OF CHRONOMETERS AND TIME SERVICE.

The heads of this department during the year have been as follows: Prof. H. M. Paul, U. S. N., from July 1 to September 16; Lieut. A. N. Mayer, U. S. N., from September 16 to June 20; Computer M. E. Porter, from June 20 to June 28; Lieut. B. W. Hodges, U. S. N., from June 28 to the end of the year.

Professor Paul was on duty in this department from July 1 to September 24, and Computer M. E. Porter from July 16 to the end of the year. Lieut. B. W. Hodges makes the following report:

CHRONOMETERS.

SIR: The continued demand for chronometers during the first half of the year made it impossible to have any temperature trial during the winter.

During the early part of the year twelve new chronometers were purchased. Most of these were issued before the war with Spain closed. When the war was over a large number of chronometers were returned to the Observatory from the ships. A large proportion of these were in need of cleaning and repairing, and were sent to the makers.

The following table shows the number of chronometers received and issued during the year:

	Turned in from—				Issues.			
	Purchased.	Ships.	Shore stations.	Makers, repaired.	To ships	To shore stations.	To makers for repairs.	Expended.
M. T. standards	13	128		42	87		69	1
M. T. hacks		23		23	12		21	
M. T. brk. circ			2	1	1	2	2	
Sid. brk. circ				1	2			
Sid. standard								
Thermometric							2	

The above table includes the chronometers received and issued at Mare Island, Cal., in addition to the same for the Observatory.

The following table shows the present location of all the seagoing chronometers belonging to the Navy:

	In service afloat.	At Mare Island.	At shore stations.	Ready for issue.	Undergoing repairs.	Total.
M. T. standards	202	26	9	40	42	319
M. T. hacks	54	7	19	10	7	97
M. T. brk. circ	1	1	4		1	7
Sid. brk. circ	2	2	5		2	11
Sid. standards		1	1			2
Thermometric			2		2	4
Pocket				5	1	6
Total	259	37	40	55	55	446

Besides the above there are 26 worn-out hacks which are condemned for use at the Observatory. But few of these are of any use.

Twenty-one chronometers are held at the Observatory on account of their historical interest.

WATCHES.

The following table shows the number of stop and comparing watches:

	Purchased.	Issued.	Received.	Repaired.	Being repaired.	On hand.	Held for repairs.
Comparing	21	48	57	19	18	30	2
Stop	25	23	19	4	13	15	2

During the year 6 torpedo-boat watches were purchased and 2 were issued. They are to be used on board torpedo boats in place of chronometers.

THERMOMETERS.

During the year 26 maximum and minimum thermometers have been issued to ships, and 31 are now ready for issue. Fifty have been purchased.

THE TIME SERVICE.

The three standard clocks, and the two clocks for transmitting noon signals, have performed fairly well. Noon signals were sent out every day in the year except Sundays. The average error for the year of the noon signals (seventy-fifth meridian time) was 0.14 seconds. The reports from branch hydrographic offices continue to show that the signal is received with a fair degree of regularity.

Between February 23 and April 23, 21 signals were transmitted at 10 p. m. They were for United States Coast and Geodetic Survey to be used at Columbia College, New York.

The wire intervals of the transit have been redetermined.

Fifty observations were made of stars whose declinations average about 80. The following values are the mean of the 50 results:

A_1 37.89	B_1 19.23	C_1 3.14	D_1 15.14	E_1 29.89
A_2 35.94	B_2 17.61	C_2 1.58	D_2 17.56	E_2 32.59
A_3 34.31	B_3 15.03	C_3	D_3 19.12	E_3 34.14
A_4 32.81		C_4 1.69		E_4 35.92
A_5 30.31		C_5 3.18		E_5 37.64

Very respectfully,

B. W. HODGES,
Lieutenant, U. S. N., Head of Department.

The department of magnetism has been discontinued, as noted in the last report of the superintendent, and the department of meteorology has been placed in charge of Professor Skinner. A new standard barometer has been mounted, the meteorological instruments have been put in good order, and observations have been continued as previously.

The following changes in the personnel of the Observatory have taken place during the fiscal year:

Capt. Charles H. Davis, U. S. N., reported for duty as superintendent on November 1, 1898, relieving Commodore Robert L. Phythian, U. S. N., who was detached on that date.

Lieut. Charles C. Marsh, U. S. N., reported for duty on January 26 and was assigned to the department of nautical instruments, but was detached on January 30, 1899.

Lieut. A. N. Mayer, U. S. N., in charge of the departments of nautical instruments and chronometers and time service, reported for duty on September 16, 1898, and was detached on June 20, 1899.

Lieut. Ben W. Hodges, U. S. N., reported for duty on June 28, 1899, and was assigned to the departments of nautical instruments and chronometers and time service.

Computer M. E. Porter was detached from the transit circle and sent to the time service on July 15, 1898.

Prof. John R. Eastman was retired for age July 29, 1898, but on account of the Spanish war he remained on duty at the Observatory until October 12, 1898. He was originally appointed as aid on November 7, 1862, and was promoted to be professor of mathematics, United States Navy, February 17, 1865.

Mr. Aaron N. Skinner was promoted from assistant astronomer to professor of mathematics, United States Navy, on July 30, 1898. He had served continuously at the Observatory since March 28, 1870, when he was appointed an aid.

Mr. John N. James, electrician, resigned July 31, 1898.

Mr. R. H. Charles was appointed to be electrician August 1, 1898, vice Mr. John N. James, resigned. Mr. Charles was originally appointed as engineer February 17, 1898.

Mr. Frank B. Littell was promoted from computer to assistant astronomer on August 6, 1898.

Computer W. S. Eichelberger was transferred from the Nautical Almanac Office to the Observatory on August 15, 1898.

Mr. George H. Peters was appointed photographer on August 15, 1898, vice Charles T. Fellows, deceased.

Mr. William F. Gardner, instrument maker, died December 11, 1898. He was first employed in the Observatory on September 8, 1864, and was promoted to be instrument maker on November 1, 1866.

Mr. J. W. Davison, employed in the library, left the Observatory on February 3, 1899, and his place was supplied by Kenneth B. Turner, formerly employed in the Treasury Department, with whom he had exchanged positions.

Prof. T. J. J. See reported for duty at the Observatory on March 2, 1899.

Prof. H. M. Paul was detached from the Observatory on March 3, 1899.

Mr. H. C. Cleve reported for duty as instrument maker on March 7, 1899, vice William F. Gardner, deceased.

Prof. Edgar Frisby, U. S. N., was retired for age May 22, 1899. He was originally appointed as an aid on June 22, 1868, and was promoted to be professor of mathematics, United States Navy, June 11, 1878.

I invite the attention of the Bureau to the recommendation of the head of the departments of chronometers and time service, and nautical instruments in which I concur that a separation should be made of these departments, and a separate officer placed in charge of each as provided by the regulations governing the organization of the Observatory. The necessity for this division, in the interests of efficiency, is sufficiently manifest. I recommend that another navy officer be assigned to duty at the Observatory to take charge of the department of nautical instruments and general storekeeper.

BUILDINGS, GROUNDS, AND ROADS.

The buildings are in excellent condition. The small appropriation for repairs has been sufficient to keep the buildings in order. With material saved from year to year, and with the balance of the year's appropriation for repairs, a new barn has been erected for the two dwellings of observers. A house for the meridian mark for the new transit circle has also been erected.

The underground passage from the boiler house to the stables and superintendent's quarters, appropriated for last year, has been completed; the steam pipes and electric wires have been established in it and it has become possible to do away with the overhead wires and to make a return of condensed water from steam heaters, which formerly ran to waste, to the boilers. It is believed that this will result in an economy of fuel.

An offer has been made for the first time for the purchase of a portion of the land belonging to the Observatory, lying outside the Observatory circle, the condemnation and sale of which was provided for by the act of August 1, 1894. In this connection I desire to renew my recommendation, already made to the Department, that no further sales, except the single one now under consideration, be made of these lands. The act above referred to protects the Observatory from encroachments within the limits of the prescribed circle; but it does not of necessity compel the Observatory to part with the land lying outside those limits, nor to acquire the sections not now owned by the Observatory which lie inside the circle. The one act is made conditional on the other. Neither does the law contemplate the completion of the public roadway about the boundaries of the circle, except the small segment of the circle contained in Massachusetts avenue extended, on the north. The application of the law in so far as it related to the sale of outside and purchase of inside land was rendered impossible by failure to receive the price fixed by the board of appraisal.

In the meantime it has been proposed by certain property owners to extend the roadway to complete another portion of the circle. As I understand it, the agreement of the Department is necessary to this object, and I most strongly recommend that that agreement be withheld or withdrawn. The proposal was made solely in private interests.

I would remind the Bureau that it was an exactly similar experience, viz, the needless encroachments in its neighborhood which helped to make the former site of the Observatory untenable. In 1875 the speculative grading of adjacent streets, which have remained unfinished and unoccupied to the present day, together with the condition of the Potomac flats, forced the Observatory to seek a site where it would be free from such nuisances. It would be an act of folly with this experience knowingly to permit similar encroachments tending to defeat the very object of the law of 1894 in the new site if they can be prevented.

I recommend that the whole question of the Observatory circle, and the disposal of the land, and the laying out of roads, be allowed to rest and remain as it now is until the extension of population in the immediate neighborhood operates to legitimately advance land values and compels a reconsideration of the question, and that then and not till then the question be reopened and reconsidered under the law of 1894. I except from this recommendation the proposal above noted, now under consideration.

BOARD OF VISITORS.

In June 1899, and for the first time in the history of the Observatory, a board of visitors was appointed by the Secretary of the Navy to examine and report upon the condition and requirements of the institution. It should be noted that a suggestion for such a board had been made more than once by previous Superintendents; but the persistent attacks upon the management of the Observatory made by irresponsible parties, using the public press as a convenient vehicle for anonymous abuse, led to an inquiry at the annual conference of American astronomers and astrophysicists in Cambridge in the summer of 1898, and the appointment of a committee of that body. The committee was met by the obstacle that, having no official (governmental) status, its inquiry and investigation of a Government institution was a gratuitous act, having no official meaning or value whatever. Under the circumstances, the Department considered the proposal for a board of visitors and assigned as the scientific members of that board the same gentlemen who had been named as a committee by the conference. These gentlemen, with a member each of the Senate and House Committees on Naval Affairs, accepted the invitation. The report of the board is expected shortly.

LIBRARY.

Assistant Librarian William D. Horigan has direct charge of the library, under the general supervision of the library committee.

	Volumes.	Pamphlets.	Total.
Contents of the library July 1, 1898	16,600	3,567	20,167
Accessions	450	169	619
Contents July 1, 1899	17,050	3,736	20,786

Of the accessions, 368 were received as exchanges and 251 were purchased.

The following publications were distributed:

Report of the Superintendent for 1898.

The Second Washington Catalogue of Stars, 1892, Appendix I, by Prof. J. R. Eastman, United States Navy.

I am, sir, your obedient servant,

C. H. DAVIS,
Captain U. S. N., Superintendent of Naval Observatory.

The CHIEF OF THE BUREAU OF EQUIPMENT,
Navy Department.

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